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# THE RELATIONS OF MAGNETITE AND ILMENITE IN THE MAGNETITE DEPOSITS OF THE DULUTH GABBRO*

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## INTRODUCTION

Of the papers[1] published in America on the titaniferous magnetites as studied by reflected light, only those of Singewald mention the deposits found within the Duluth gabbro. Singewald described the deposits of a limited area. The Minnesota Geological Survey has mapped the deposits in detail and Broderick[2] has discussed the results of much of this work. In connection with further work of the survey on the magnetites of the state the writer has examined the relations of the minerals by reflected light in over 100 specimens of the magnetite ore and gabbro representing every important outcrop. The distribution of these deposits is shown on Figure 36 of Broderick's paper where the details of the geology are also described. The data presented here are mainly limited to the relations of ilmenite and magnetite and the bearing of these relations and other data on the origin of the deposits.

## THE RELATIONS OF ILMENITE AND MAGNETITE

Most of the specimens examined were from the four types of

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[1] Singewald, J. T., The microstructure of titaniferous magnetites: *Econ. Geol.*, vol. **8**, pp. 202–214, 1913; The titaniferous iron ores of the United States: *Bur. of Mines Bull.* **64**, 1913. Brunton, S., Some notes on titaniferous magnetites: *Econ. Geol.*, vol. **8**, pp. 670–680, 1913. Warren, C. H., On the microstructure of certain titanic iron ores: *Econ. Geol.*, vol. **13**, pp. 419–446, 1918. Bayley, W. S., The occurrence of rutile in the titaniferous magnetites of western North Carolina and eastern Tennessee: *Econ. Geol.*, vol. **18**, pp. 362–392, 1923. Osborne, F. F., Certain magmatic titaniferous iron ores and their origin: *Econ. Geol.*, vol. **23**, pp. 724–761, 1928.

[2] Broderick, T. M., The relation of the titaniferous magnetites of northeastern Minnesota to the Duluth gabbro: *Econ. Geol.*, vol. **12**, pp. 663–696, 1917.

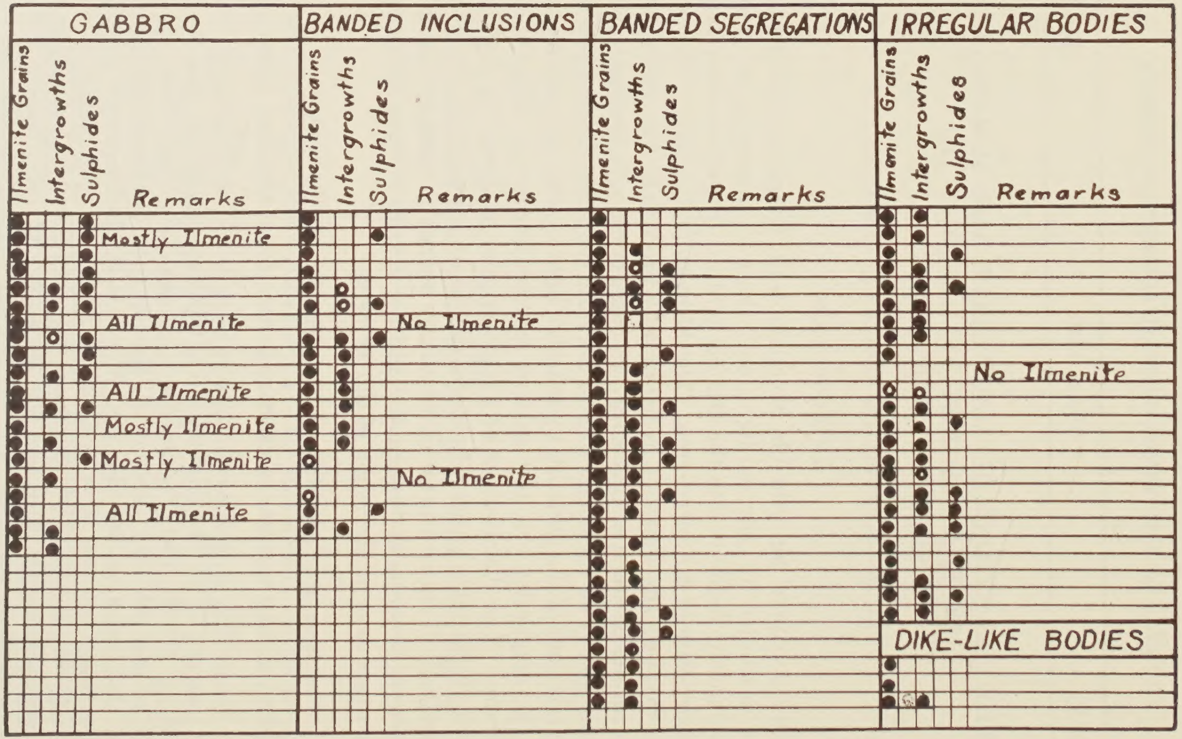
GABBRO
Ilmenite Grains
Intergrowths
Sulphides
Remarks
Mostly Ilmenite
All Ilmenite
All Ilmenite
Mostly Ilmenite
Mostly Ilmenite
All Ilmenite
BANDED INCLUSIONS
Ilmenite Grains
Intergrowths
Sulphides
Remarks
No Ilmenite
No Ilmenite
BANDED SEGREGATIONS
Ilmenite Grains
Intergrowths
Sulphides
Remarks
IRREGULAR BODIES
Ilmenite Grains
Intergrowths
Sulphides
Remarks
No Ilmenite
DIKE-LIKE BODIES

FIG. 1. Tabulation showing the form of ilmenite in magnetite ore and gabbro specimens from various types of deposits in the Duluth gabbro.

titaniferous magnetite deposits as classified by Broderick.[3] These are as follows: (1) Inclusions of banded Gunflint iron formation. (2) Banded segregations of the gabbro. (3) Irregular bodies of titaniferous magnetite. (4) Dike-like bodies of titaniferous magnetite. Several of the specimens were of gabbro found near the magnetite masses and, as might be expected, this gabbro is high in magnetite and ilmenite. An attempt has been made to bring out some of the facts as to the opaque constituents in Figure 1.

As far as could be determined, the titanium occurs mainly as ilmenite which is found abundantly in the ores as grains and as intergrowths of ilmenite along the parting planes of magnetite. Because of the emphasis placed on them, one might think that ilmenite occurs in titaniferous magnetites mainly in the form of intergrowths but this is not true of the deposits in the Duluth gabbro as is shown in Figure 1, nor it is true of deposits in general, according to Singewald. A rough estimate would indicate that not more than 15 per cent of the ilmenite is present as intergrowths.

A glance at Figure 1 shows that ilmenite is found as separate grains in all specimens which show the mineral. The grains vary from microscopic size to a maximum diameter rarely above 5 mm. There is also a great variation in the number of grains on a given polished surface. Some surfaces have only two or three ilmenite grains, whereas others are made up largely of that mineral. A common type is a granular aggregate of ilmenite and magnetite grains of about the same size. A few of the grains of ilmenite when etched show a series of parallel lines or bands and where these are wide enough the dark material may be recognized as magnetite. (See Figure 7). There is a distinct variation in the nature of the surfaces of the polished ilmenite grains. Many show a rough surface due to the presence of innumerable fine pits whereas others in the same specimen are smooth and highly polished. Both types are common and the only explanation which suggests itself is that the difference is due to varying orientation, as in some specimens the pits are elongated in one direction.

In a few specimens minute euhedral crystals of ilmenite were noted in magnetite, but this is an unusual feature.

The intergrowths of ilmenite in magnetite present the most interesting phase of the relations. As shown in Figure 1, 56 out of the 95 specimens tabulated show intergrowths of some kind. These are of great variety and only the more general types can be noted. On etched polished surfaces, the ilmenite is seen as lines or dashes, rarely dots, but the dots are not found in abundance, nor are they normally aligned along the parting as described by Singewald for other deposits. Warren[4] reported that the dots are usually rutile, and this has been verified by Osborne.[5] Blade-like forms, as viewed in two dimensions, are formed by plates of ilmenite along parting planes in magnetite and are by far the most common form of inclusion. The size of the ilmenite blades varies from extremely minute up to those visible to the naked eye, as is brought out in the series of micrographs shown in Figures 2 to 6, which have been reproduced at the same magnification for comparative purposes. The most minute dashes can be identified only with high power, 200±, but those shown in Figure 2 are easily seen at a magnification of about 80 and are approximately .001 mm. wide and .02 mm. long. The smallest recognized are perhaps not over .0005 mm. wide and .005 mm. long. The largest are about .1 mm. wide and nearly a centimeter long, and may be seen with the naked eye. (See Singewald: *U. S. Bur. Mines Bull.* **64**, Plate 8B). The variation in the number and spacing of the ilmenite lines is equally great. Some magnetite grains are closely crowded with ilmenite lines, as in Figure 4, whereas others have only a few blades, as in Figure 6. The close crowding shown in Figure 4 is remarkable in view of the common occurrence of ilmenite as grains. It might be expected that this ilmenite would have segregated into grains, but for some unknown condition of formation this did not occur.

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[3] *Op. cit.*, p. 677.

There is also a great variation in the number of ilmenite blades within the magnetite grains of a given specimen. In some specimens all the magnetite grains are filled with intergrowths, in others part of the grains are free from ilmenite, while adjacent grains have closely spaced ilmenite blades. There is apparently no end to the variety shown by a large number of specimens from this one igneous mass.

In many of the polished specimens ilmenite occurs along the contacts of grains of magnetite, a fact brought out by the grain structure which shows so clearly after etching in hot HCl. Figures 11 and 12 show typical examples of this texture which have been

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[4] *Op. cit.*

[5] *Op. cit.*

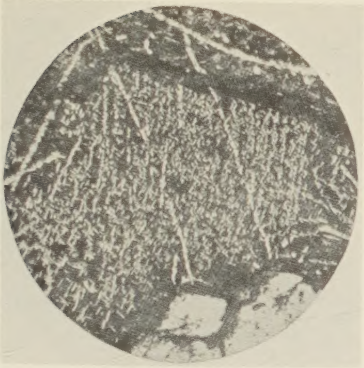

FIG. 2. Fine dash type of ilmenite intergrowths in magnetite. Tucker Lake, Minnesota. Mag. X 73.

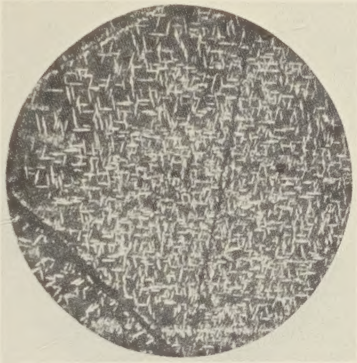

FIG. 3. Coarser dash type of ilmenite intergrowths in magnetite. Iron Lake, Minnesota. Mag. X 80.

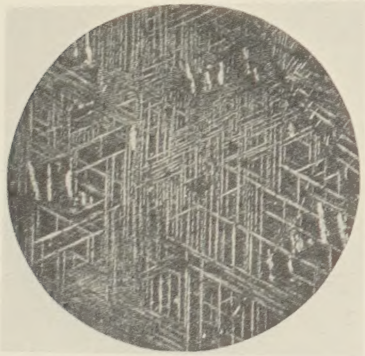

FIG. 4. Closely crowded ilmenite plates along the parting of magnetite. Essentially the Widmanstätten structure. Tucker Lake, Minnesota. Mag. X 80.

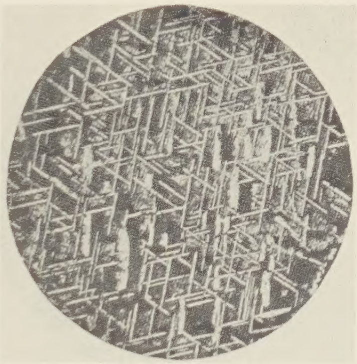

FIG. 5. Fairly coarse intergrowth of ilmenite in magnetite. North shore Pillsbury Lake. Mag. X 80.

PLATE I. Micrographs of etched polished surfaces of titaniferous magnetites from the Duluth gabbro. Shows the gradation in the size of the ilmenite intergrowths.

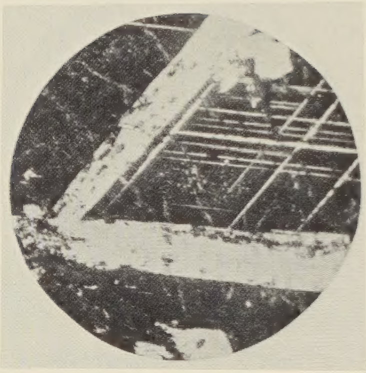

FIG. 6. Coarsest plates of ilmenite observed in magnetite. South of Snowbank Lake, Minnesota. Mag. X 73 (Etched).

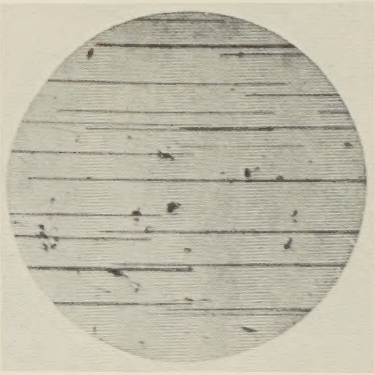

FIG. 7. Parallel intergrowths of magnetite in ilmenite. Homer Lake, Minnesota. Mag. X 80 (Etched).

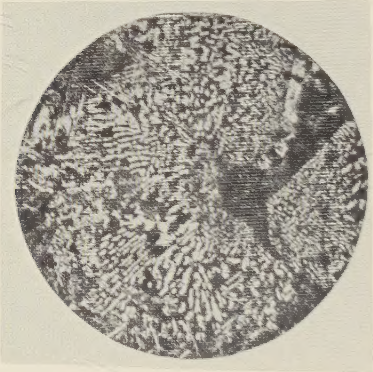

FIG. 8. Graphic intergrowth of hematite (white) and magnetite. Hematite apparently secondary. Some blades of ilmenite around edges. (Etched). Poplar Lake, Minnesota. Mag. X 125.

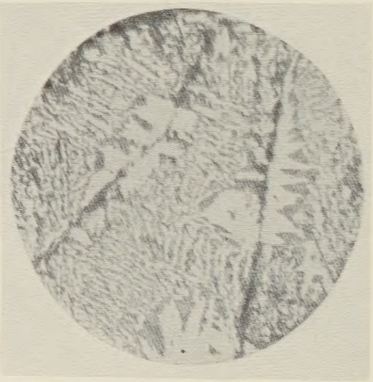

FIG. 9. Graphic intergrowth of ilmenite (white) and hornblende. Anorthositic gabbro, (unetched). Duluth, Minnesota. Mag. X 112.

PLATE II. Micrographs of polished surfaces of titaniferous magnetites from the Duluth gabbro.

attributed by Van der Veen[6] to segregation along grain boundaries during the slow cooling of a solid solution which breaks down into two minerals. This explanation is not entirely satisfactory as the cooling of the tremendous mass of the Duluth gabbro must have been very slow so that one would expect that all of the ilmenite would have been eliminated from the magnetite, whereas often considerable is left as inclusions in the magnetite. The texture represented by Figures 2 to 6 doubtless results from the breakdown of a solid solution as has been shown by Ramdohr.[7]

Textures which have not received much attention heretofore were noted in some of the specimens. These were the so-called graphic intergrowths or pseudo-eutectic textures as they have been recently called by Lindgren.[8] Figure 8 shows a photograph of a specimen from Poplar Lake with a well defined intergrowth which was at first thought to consist of magnetite and ilmenite, but on further study the texture was found to be due to hematite, although ilmenite is also present in small amounts. This texture seemed to have resulted from oxidation as it is limited to a small area around silicate contacts or fractures. A rather common type of intergrowth is represented by Figure 9 in which ilmenite is intergrown with hornblende, presumably of deuteric origin. Plagioclase also appeared intergrown with ilmenite in the polished specimen.

A single thin section of a specimen from south of Brule Lake showed ilmenite as graphic intergrowths with plagioclase, augite, biotite and secondary minerals, particularly chlorite. In this type it seems evident that part of the ilmenite crystallized with the silicates presumably later than the crystallization of the greater part of the magnetite and ilmenite. Osborne[9] has noted that some of the ilmenite crystallized later than the magnetite in the deposits described by him.

The intergrowth described above could scarcely represent an eutectic deposition as ilmenite could not form an eutectic with plagioclase, augite and biotite within the limits of a single thin section. The presence of alteration products in some of the intergrowths completely replacing the primary silicate minerals presents an interesting case and emphasizes the difficulty of interpreting these textures.

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[6] Van der Veen, R.W., Mineragraphy and ore deposition. The Hague.

[7] Ramdohr, Paul, Beobachtungen an Magnetit, Ilmenit, Eisenglanz und überlegungen über das System FeO, $Fe_2O_3$, $TiO_2$. *Festschrift zur 150 Jahrfeier der Bergakademie Clausthal*, pp. 304–341, 1925.

[8] Lindgren, W., Pseudo-eutectic textures: *Econ. Geol.*, vol. **25**, pp. 1–13, 1930.

[9] *Op. cit.*

The greater part of the magnetite in the various deposits is usually granular, a fact which shows up well after etching with hot concentrated HCl. It is common to find subhedral crystals with perhaps one or two faces well developed.

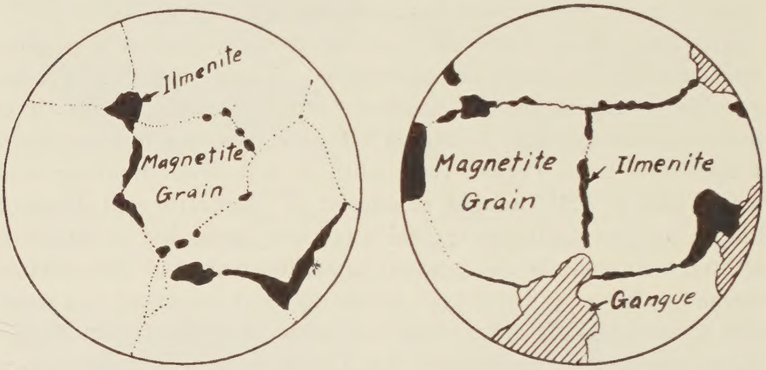

FIG. 10 and 11. Sketches of etched polished surfaces showing the tendency of ilmenite to occur along the contacts of grain boundaries. Figure 10, Thomas Lake, Minn. Figure 11, Little Saganaga Lake, Minn. Mag. X 18.

A noteworthy fact developed during the study is the prevalence of sulphides in the magnetite-ilmenite ores and gabbro. As shown in Figure 1, 31 out of 95 specimens tabulated contained sulphide, normally only chalcopyrite, but rarely pyrite, pyrrhotite, bornite and chalocite. The sulphide is usually present as minute specks and no tendency to segregate into masses was noted. The writer has previously expressed an opinion regarding the significance of this fact in connection with the relative scarcity of epigenetic deposits as a result of the intrusion of basic rocks.[10]

Most of the specimens examined were from outcrops and thus show some weathering. This is superficial, however, as the deposits were well scoured by glacial action. Magnetite is characteristically attacked along fractures and grain boundaries with hematite penetrating the grains along the octahedral planes, as shown in Figure 12. The fractures also pass through ilmenite grains but little hematite is developed in them due to the resistance of ilmenite to alteration. No advanced stages of replacement of magnetite by hematite were noted. Evidently oxidation has been very slight since glacial time. The silicate minerals usually show more alteration than magnetite; limonite especially resulting from the alteration of olivine.

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[10] Schwartz, G. M., Contact effects of gabbro and granite on ore deposition: *Econ. Geol.*, vol. **19**, pp. 681–684, 1924.

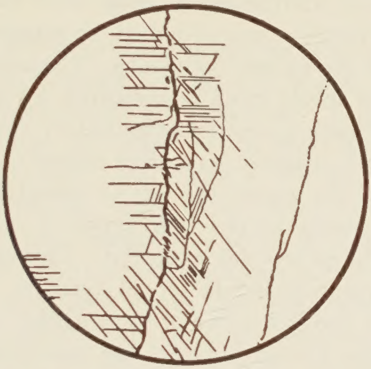

FIG. 12. Sketch of an etched polished surface showing the presence of hematite intergrowths in magnetite along a fracture filled with hematite. Duluth gabbro, Tucker Lake. Mag. 32 X.

## BEARING OF THE RELATIONS ON THE ORIGIN OF THE MAGNETITE DEPOSITS

Broderick[11] recognized four types of magnetite deposits as follows: inclusions of banded Gunflint iron formation, banded segregations of the gabbro, irregular bodes of titaniferous magnetite, dike-like bodies of titaniferous magnetite. Of these the first and last two were believed to be due to the incorporation of iron formation in the gabbro, whereas the second was called a segregation. A study of the field relations of those deposits farthest in the gabbro, southwest of Brule Lake, shows that even there muscovadite (metamorphosed rock included in gabbro)[12] is characteristically associated with these segregations. Grout and Broderick[13] report that in practically every case a magnetite deposit of any size has muscovadite associated with it. This strongly suggested to Mr. Broderick that the banded segregations are only in a limited sense segregations, inasmuch as a considerable part of the iron oxide was supplied by inclusions and passed into the melt only to crystallize out in most cases near to the point of inclusion. The titanium was added to the magnetite as postulated by Broderick for the known inclusions. The addition of titanium to the iron oxide in all cases is indicated by its distribution as brought out in Figure 1, and is suggested by the fact that part of the ilmenite may be slightly later than magnetite. As far as could be determined by the writer, there is no essential difference in the occurrence of ilmenite in the four types of magnetite deposits, although some difference was expected. This is at least strongly suggestive of a common origin for all deposits. The distribution of the deposits is also indicative of some agency other than simply segregation as the known deposits are practically limited to an area along the north and northeast boundaries of the gabbro, where the Biwabik Gunflint iron formation was engulfed. The total area within which deposits are found is not over 15 per cent of the gabbro, and this 15 per cent is adjacent to formations lying below the iron formation.

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[11] *Op. cit.*, p. 677.

[12] For description of metamorphic effects of gabbro, see Schwartz, G. M., Contrast in the effect of granite and gabbro intrusions on the Ely greenstone: *Jour. Geol.*, vol. **32**, pp. 89–138, 1924.

[13] Personal communications.

Quantitative data on the inclusions and amount of assimilation by the gabbro near some of the magnetite deposits have been obtained by Dr. Grout[14] and are suggestive in this connection.

The writer is indebted to Dr. T. M. Broderick and Dr. F. F. Grout for the suggestion regarding the source of much of the iron ore in these deposits.

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[14] Grout, F. F., The probable extent of abyssal assimilation: *Bull. Geol. Soc. America.* In press.

# THE MINERALOGY OF SOME DEPOSITS OF KAOLINIZED VOLCANIC ASH FROM THE SLATE BELT OF NORTH CAROLINA

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## Introduction

The Slate Belt of North Carolina embraces a region which varies in width from 8 to 50 miles and extends across the center of the State in a northeast-southwest direction. The belt reaches its maximum width near the center of the State and narrows to the northeast and southwest. The rocks of this area, because of their well developed cleavage, have been called slates. The whole Slate Belt has not been mapped in detail, but field investigation, petrographic study, and chemical analyses of the rocks from different parts of the belt have shown that the slates are of volcanic origin. In the areas studied the slates are composed of the following materials: (1) flows of rhyolite, dacite, andesite and related rocks; (2) beds of volcanic ash, tuff and breccia of the same general composition as the flow materials; (3) beds of slate composed of the finer ash and tuff materials and land waste.

The metamorphic forces which changed these materials to slates did not act uniformly throughout the whole area. In the northern half of the Slate Belt the rocks are highly slaty and schistose with a well developed cleavage that dips steeply to the southeast, while in the southern half the cleavage is in may areas less well developed and dips to the northwest. In a number of places, particularly along the Seaboard Railway between Wadesboro and Monroe, original bedding planes are well preserved.

Scattered throughout the Slate Belt, but especially common in its southeastern portion in Moore, Montgomery and Richmond counties, are beds of a residual gray to white clay commonly referred to as kaolin. This material while quite similar throughout the area varies from place to place. Some outcrops grade downward into a massive and jointed material while others are distinctly schistose beneath the surface. This study deals with the difference between the massive and schistose phases. In all the deposits the clay has a soft, smooth feel, but gritty material is much more common in some occurrences than in others. The beds are all distinctly lenticular in shape and irregular in size, and vary in areal extent from a few square yards to several acres and in depth up to 25 or 30 feet.

As early as 1897 Ries[1] studied and tested samples of this material from Richmond and Montgomery counties which yielded upon washing from 15 to 40 per cent of clay substance. Tests showed that this clay substance compared favorably with standard kaolin.

Bayley[2] while studying the kaolin of North Carolina in 1918 visited Montgomery and Richmond counties and described some of the deposits. Describing the Overton deposit near the Iola Gold Mine at Candor he says: "The sample furnished is a loose, very light pinkish gray, gritty, flour-like mixture of very fine quartz and kaolin.****Under the microscope the principal constituents are quartz grains of all sizes from the most minute to those 0.2 millimeter in length. Perhaps the greatest number have diameters between 0.05 and 0.06 millimeter. Besides these are a few white opaque grains with straight edges that may be altered feldspar grains and a fair quantity of small kaolinite particles of about the size of the smallest quartz particles. Occasionally there is a shred of kaolinite 0.06 millimeter long but most particles are less than 0.004 millimeter across."

Describing the Eames Prospect near Mount Gilead he says: "The sample looks very much like that from the Iola Mine at Candor. It is a very fine, gritty, flour-like material of a very pale grayish white color. The crude material is made up mainly of small quartz grains with diameters between 0.02 and 0.04 millimeter. In addition there are a few particles of rutile, hydromica and strained feldspar and a very few tiny plates of kaolinite. The quartz is in little sharp-edged splinters, in subangular grains, in very irregular shaped particles and in a very few cases in rounded grains. Evidently the material has not been carried far from its source. It may be a residual mass, like that at the Iola Mine from which most of the kaolinite has been removed." He concludes that the material probably has been formed from a fine-grained, volcanic rock.

## Nature of Deposits and Methods of Study

During the past two or three years interest has been revived in these clays and attempts have been made to find uses for them. In addition to the occurrences studied by Ries and Bayley other deposits have been prospected, three of which are described below. One of these lies along Drowning Creek in the western edge of Moore and the eastern edge of Montgomery counties, some 5 miles west of Eagle Springs. Another lies in Randolph county 4 miles west of Staley and about 25 miles south of Greensboro. The third deposit is located in Granville county about 2 miles north of Stem and some 20 miles south of the Virginia line. Careful field investigation of the three areas indicates that each deposit is associated with and occurs in acid volcanic rocks that consist chiefly of ash and fine tuff.

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[1] Ries, H., Clay Deposits and Clay Industry in North Carolina: *N. C. Geol. Survey Bull.* **13**, pp. 64–70, 1897.

[2] Bayley, W. S., Kaolins of North Carolina: *N. C. Geol. Survey Bull.* **29**, pp. 126–127, 1925.

Seven samples were collected from these three deposits for study, 5 of which came from the deposit on Drowning Creek in Moore and Montgomery counties, and one each from the deposits near Staley, Randolph county and Stem, Granville county. Wet screen tests, partial chemical analyses and microscopic examinations were made.

For screen tests samples of each clay were crushed to disintegrate any lumps present, care being taken to avoid grinding or reducing the natural grain size. Portions of exactly 300 grams each were weighed out and put into 500 cc. of water to which a few drops of $NH_4OH$ were added. The samples were left over night and screened through a nest of hand screens consisting of the 150 mesh screen above the 200 mesh. The results of the screen tests are given in Table 1, and partial chemical analyses are recorded in Table 2.

Microscopic study was carried out by mounting the clays in index liquids which recently had been standardized. A small particle of the material was placed on a glass slide and crushed with the thumb nail, a few drops of the index liquid were added and a cover glass placed over the mount. The minerals present were determined by indices of refraction and general optical properties, including interference figures where possible.

## Description of Samples

Drowning Creek has cut through the deposit in Moore and Montgomery counties to the parent material below, and by deflection against its southern bank has produced a bluff some 15 feet high. All the evidence obtained indicates that the clay is residual. The outcrop is jointed but much freer from schistose structure than deposits farther north in the Slate Belt. The clay is gray to white in color while the bed rock just above the water level in the creek is gray to yellow. About 1000 feet to the south of the stream bed rock is exposed at the surface as a crudely stratified, gray to pinkish colored material.

Five samples were taken from this deposit for study as follows: one sample from the parent rock just above the water level of the stream, one sample of the bed rock about 1000 feet south of the stream, and three samples at different levels from the stream bluff.

*Sample 1.* The parent material from just above the stream level though badly weathered resembles in hand specimen the fine-grained, fragmental materials characteristic of the Slate Belt. In structure it is only slightly schistose while the color is distinctly gray to yellow. The microscope shows a fragmental material composed of angular and irregular grains of quartz and feldspar in a fine grained matrix. Quartz is a common mineral occurring as splinters and sharp edged grains. Feldspar is present in partly altered grains. Small amounts of epidote, kaolinite, sericite and iron oxides are present in a fine-grained ground mass some of which is non-polarizing.

*Sample 2.* The bed rock from the north end of the deposit is a crudely stratified material which contains gray and chocolate colored layers. It is extremely fine-grained and sufficiently weathered to break readily in one's hands and crumbles into a pink colored powder. The microscope reveals a very fine-grained material much like that in sample 1, the chief difference being that this is much finer grained. Quartz and feldspar are present in small amounts as angular grains in a very fine-grained ground mass. The finer materials consist of tiny grains and shreds of epidote, iron oxides, kaolinite, and sericite in a mass either non-polarizing or too fine to identify.

*Sample 3.* A sample of the clay taken from the bluff two or three feet above the parent rock is a soft, gritty, rather white, flour-like material free from lumps and fragments. The microscope shows quartz common in angular, splinter-edged and curved faced grains, the greater part of which vary between 0.02 and 0.04 millimeter in diameter. Kaolinite is abundant in shreds and plates about the size of the smaller quartz grains, while fan and worm shaped masses two or three times the size of the largest quartz grains are common.

A few grains of halloysite, sericite, hydromica, rutile and titanite are also present.

*Sample 4.* A sample of the clay taken about midway between the top and bottom of the bluff is a grayish white, rather gritty, flour-like material containing a few yellow streaks probably due to iron stain. Quartz is abundant in irregular and angular grains 0.01 to 0.03 millimeter in diameter. Kaolinite is common in tiny shreds and flakes and sparingly in excellent plates. Small amounts of sericite, hydromica and rutile are also present.

*Sample 5.* A sample taken from just beneath the soil is distinctly gray in color, rather gritty and free from lumps. The most common mineral identified is quartz. It occurs in irregular grains of dust-like size that vary from 0.003 to 0.02 millimeter in diameter. Much fine-grained material like kaolin is present though no definite flakes or fan structures were seen. Small amounts of sericite, some hydromica and titanite are present in a fine-grained dirty ground mass much of which is non-polarizing.

The deposit near Staley, Randolph County, occurs as the hanging wall of a pyrophyllite body, but some 50 feet away from the mineralized zone in which the pyrophyllite is found. It has been prospected by a trench 40 feet long and a pit 20 feet deep. In the pit the material has a well developed schistose structure which dips steeply to the northwest.

*Sample 6.* A representative specimen from this pit crumbles readily in one's hands to a very fine, flour-like material, free from any gritty feel and is light gray to white in color. Microscopic examination shows quartz abundant as dust-like fragments with a maximum diameter of 0.02 millimeter. Kaolin is sparingly present in tiny particles a very few of which are doubtless distinct flakes of kaolinite. Sericite is abundant in characteristic scales and fibers. Rutile is common in needles and elbow twins, while titanite is occasionally found.

In the deposit near Stem, Granville County, the material as exposed in a small pit on the side of a hill has an extreme schistose structure that dips steeply to the southeast.

*Sample 7.* A hand specimen from this pit crushes readily to a fine-grained, flour-like material that is free from any gritty feel and is light gray to white in color. Under the microscope quartz and sericite are the only minerals readily determined. The shape and size of the grains are much like those already described, particularly in sample 6, and need not be repeated.

Table 1. Wet Screen Tests of Samples

| | 1<br>Per Cent | 2<br>Per Cent | 3<br>Per Cent | 4<br>Per Cent | 5<br>Per Cent | 6<br>Per Cent | 7<br>Per Cent |
|---|---|---|---|---|---|---|---|
| On 150 Mesh | 29.93 | 2.86 | 29.20 | 30.23 | 6.16 | 0.40 | 2.16 |
| On 200 Mesh | 1.46 | 0.20 | 2.76 | 1.56 | 2.93 | 0.53 | 0.50 |
| Total through 200 Mesh | 68.61 | 96.94 | 68.04 | 68.21 | 90.91 | 99.07 | 97.34 |

Table 2. Chemical Analyses of Samples*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 59.90 | 64.70 | 70.40 | 74.40 | 75.70 | 73.20 | 67.10 |
| $Al_2O_3+Fe_2O_3$ | 29.20 | 26.00 | 22.00 | 19.20 | 19.10 | 18.70 | 22.90 |
| Ign. Loss | 7.90 | 5.50 | 4.60 | 4.40 | 4.60 | 4.72 | 3.30 |
| $Na_2O$ | — | — | — | — | — | — | 2.01 |
| $K_2O$ | — | — | — | — | — | — | 5.64 |
| Total | 97.10 | 96.20 | 97.00 | 98.00 | 99.40 | 96.12 | 100.95 |

* Analyses by G. R. Shelton, Ceramic Chemist, Bureau of Standards, Columbus Branch, Columbus, Ohio.

## Summary and Conclusions

Field evidence shows that the three deposits described lie in areas of acid volcanic rocks. Microscopic examination of samples 1 and 2 reveals a material which, though much weathered, has many characteristics of a fine tuff or volcanic ash. The other 5 samples due to weathering show little resemblance microscopically to true fragmental materials. However, the general similarity of all the materials and their association with acid volcanic rocks indicate that they were originally fine-grained tuff or volcanic ash.

The present mineral composition of these deposits seems to be related to the amount of metamorphism they have undergone. In the northern part of the Slate Belt where metamorphism has been severe the fine-grained materials doubtless have been changed directly to sericite schist, while farther south where dynamic forces were less intense they have weathered to impure kaolin.

# SODA-RICH ANTHOPHYLLITE ASBESTOS FROM TRINITY COUNTY, CALIFORNIA

J. D. Laudermilk and A. O. Woodford,* *Pomona College, Claremont, California.*

Samples of asbestos fiber and asbestos in serpentine from Coffee Creek, one mile north of Carville, Trinity County, California, were brought to our laboratory by Mr. J. M. Cowan of South Pasadena, California. One of us (Woodford) later visited the locality, a series of small, closely-spaced prospect pits on the rather steep slope at the south side of the mouth of Coffee Creek, a tributary of Trinity River. The country rock is serpentine, commonly showing bastite pseudomorphs. The serpentine contains two types of veins: (1) the usual minute, branching veinlets of chrysotile, less than a millimeter wide, and (2) much thicker amphibole asbestos veins. Practically none of the coarse asbestos is now exposed in the walls of the prospect pits, but some can be found in the rock on the dumps.

The thick veins look like dark-colored chrysotile, but are exclusively amphibole. They are short, branching, of variable width, and lie in the crushed, slickensided rock in very roughly parallel positions. The thickness of the different veins ranges from a few millimeters to five centimeters, and a single vein may pinch out very rapidly. Exceptionally a vein with maximum width of one centimeter may be only five centimeters long. The fibers are usually perpendicular to the walls, although in some veins oblique, and commonly almost as fine and flexible as commercial chrysotile. Some veins, but not all, have slickensided margins, along which the fibers have been dragged. The color of the separated fibers is white, but on fresh breaks the veins usually have the color called by Ridgway 33''''m, Dull Greenish Black.[1] There is a range from Black to 33'''k, Dark American Green, but no correlation could be made between depth of color and optical properties.

A microscopic study was carried out on thin sections and oil mounts. Indices were determined in oils, using white light, and the oils checked at once with a Spencer Abbe refractometer. The long-fibered asbestos was found to be chiefly pale, low-index anthophyllite ($\gamma = 1.623$–$1.625$; in standard thin-section X and Y colorless, Z Ridgway's 35′′f, Pale Olivine), with lesser amounts of higher-index, greenish anthophyllite ($\gamma$ about 1.630–1.635), and tremolite or actinolite ($\gamma = 1.622 \pm .002$, extinctions up to 12° and perhaps higher). In several cases a single vein yielded two types of amphibole.

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* Chemical analysis by J. D. Laudermilk; optical study by A. O. Woodford.

[1] Robert Ridgway, Color Standards and Color Nomenclature, 43 pp., 53 pls., *Washington,* **1912.**

The "No. 1 fiber," a composite sample furnished by Mr. Cowan, was chosen for chemical analysis. It was found by microscopic study to be chiefly anthophyllite with the following indices: $\alpha = 1.606 \pm .002$, $\beta = 1.613 \pm .002$, $\gamma = 1.623 \pm .001$. Parallel to the elongation of the fibers (Z) the color is pale yellow-green; the other directions are colorless except in thick bundles. There is also present in the sample some anthophyllite with slightly higher indices ($\gamma = 1.625 \pm .002$), and a deeper color. One exceptional fiber was found with a still higher value for $\gamma$, approximately 1.630. A few fibers show slightly inclined extinction (5° or less) and may be tremolite ($\gamma = 1.622 \pm .002$). Non-amphibolic impurities were estimated to make up less than 2%; they included iron oxide spots and stains, as well as minute grains of quartz, and perhaps serpentine and other minerals. The asbestos has easy fusibility, about 3, and colors the flame intensely yellow. The material is practically insoluble in acid. For the analysis half-gram samples were used. The average of closely agreeing duplicates, together with the molecular ratios, follows:

| | Weight Per Cent | Molecular Ratios |
|---|---|---|
| $SiO_2$ | 57.70 | .9607 |
| $TiO_2$ | absent | |
| $Al_2O_3$ | 2.00 | .0196 |
| $Fe_2O_3$ | trace | |
| FeO | 5.32 | .0741 |
| MgO | 21.12 | .5238 |
| CaO | 5.10 | .0910 |
| $Na_2O$ | 7.40 | .1194 |
| $K_2O$ | absent | |
| MnO | trace | |
| F | absent | |
| $H_2O$ above 110° | 1.80 | .0999 |
| $H_2O$ below 110° | 0.30 | — |
| TOTAL | 100.74% | |

The analysis may also be expressed in molecular percentages of metasilicates, as follows:

| | | |
|---|---|---|
| $NaAl(SiO_3)_2$ | 6.25% | |
| $Na_2SiO_3$ | 10.61 | |
| $MgSiO_3$ | 55.66 | |
| $FeSiO_3$ | 7.87 | |
| $CaSiO_3$ | 9.67 | |
| $H_2SiO_3$ | 9.94 | (Excess of .0064 $H_2O+$ in mol. ratios not used.) |
| TOTAL | 100.00% | |

Although there is an excess of bases, it is so small as to favor the exclusively metasilicate interpretation given. If $Al_2O_3$ were considered present in solid solution only, the deficiency of bases would be eight times the excess here shown. Of the molecules mentioned by Winchell[2] only $MnSiO_3$ is missing. Soda is so high as to require $NaAl(SiO_3)_2$ and $Na_2SiO_3$, constituents not in Winchell's list.

Very few other anthophyllite analyses show appreciable soda, and none known to us is as high in soda as the Coffee Creek material. Doelter[3] gives one high-alkali "antholith," with $K_2O$ plus $Na_2O = 5.93\%$ (also $Fe_2O_3 = 8.03\%$), analyzed by van der Bellen, who gives neither locality nor optical data in the original paper.[4] Van der Bellen mentions the light blue color, fineness and softness of this asbestos. It melted at Cone 1 (1150°C.) and lost 5% by cooking in HCl. Van der Bellen's data and ours, taken together, suggest that soda-rich anthophyllite asbestos is relatively soft and flexible.

According to Winchell's chart, showing "Variations of composition and optic properties in the anthophyllite series,"[5] the indices of our analyzed material correspond to about 11 percent by weight of $FeSiO_3$ and 89 weight percent of $MgSiO_3$. Our analysis corresponds to slightly less than 10 weight per cent of $FeSiO_3$, and 90+ percent of the other constituents. If only $FeSiO_3$ (plus $MnSiO_3$) and $MgSiO_3$ are considered, as was done in preparing the Winchell chart,[5a] then our analysis would be represented by 15.7 weight percent of $FeSiO_3$, and 84.3 weight percent of $MgSiO_3$. It seems that small amounts of soda, and probably lime also, have approximately the same effect upon the indices as does magnesia and that in the case of soda-rich anthophyllite the

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[2] N. H. and A. N. Winchell, Elements of Optical Mineralogy, 2nd Ed., Part II, p. 202, **1927**.

[3] C. Doelter, Handbuch der Mineralchemie II, 1, p. 606, **1914**.

[4] E. van der Bellen, Beitraege zur Kenntniss des Asbestes, *Chemiker-Zeitung*, **1900**, pp. 392–393.

[5] Winchell, *Loc. cit.*, p. 204.

[5a] Private communication from Professor A. N. Winchell.

Winchell diagram indicates more $MgSiO_3$ than is present.

Slavík and Veselý[6] have objected to the extension beyond 30% (Fe, Mn) $SiO_3$ of the practically straight-line Bowen chart for anthophyllite,[7] and their data may require a slight alteration in the Winchell curves. Moreover, it appears that even in the relatively simple anthophyllite series, refractive index curves must be supplemented by other data in order to obtain an adequate idea of chemical composition.

Unlike the Trinity material, most anthophyllite and other amphibole asbestos seems to occur in long-fibered bundles or irregular aggregates. When in veins it is fibrous parallel to the walls.[8] However, Merrill quotes Heddle as reporting "amianthus"[9] (tremolite) from cross-fiber veins in Scotland. More recently Peacock[10] and Slavík[11] have reported high-iron and high manganese anthophyllite asbestos in veins with cross-fiber structure. Whatever may be the causes of some such structures, for the Trinity occurrence recourse can hardly be made to Mügge's gel-shrinkage hypothesis,[12] which was developed from a study of the Reichenstein, Silesia, serpentine. This explanation seems to be eliminated here by the preservation of the bastite structures. Peacock's[13] suggestion of control by loss of the solvent through the walls of the seams is very attractive, especially in view of his evidence that crocidolitization is accompanied by dehydration. The formation of the short, wide fissures was perhaps due to stresses set up during development of the serpentine from the pre-existing rock.

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[6] Fr. Slavík and V. Veselý, Manganiferous anthophyllite asbestos from Chvaletice: *Rozpravy Ceské Akad.*, **36**, Nr. 46, pp. 1–7, 1 Text fig. French summary in *Bull. intern. de l'Ac. de Sci. de Boh.*, **1927**, Praha, 1927. Abstracts in *Neues Jahrbuch, Referate*, I, **1929**, pp. 120–121, and in *Mineralogical Abstracts* **3**, 508, 1928. Original paper not seen.

[7] N. L. Bowen, Optical properties of anthophyllite: *Jour. Wash. Acad. Sci.*, **10**, 411–414, 1920.

[8] G. P. Merrill, Notes on Asbestos and Asbestiform Minerals: *Proc. U. S. Nat. Mus.*, **18**, 281–292, 1895, especially p. 289.

[9] *Loc. cit.*, p. 286.

[10] M. A. Peacock, The Nature and Origin of the Amphibole-Asbestos of South Africa: *Am. Mineralogist*, **13**, 241–286, 1928, especially pp. 259–265.

[11] Fr. Slavík, Note sur l'anthophyllite asbeste manganésifère des mines de Jacobeni-Arsita: *Ann. sci. univ. Jassy*, **15**, 133–135, 1928. Abstract in *Mineralogical Abstracts*, **3**, 548, 1928.

[12] O. Mügge, Ueber die Entstehung faseriger Minerale und ihrer Aggregationsformen: *Neues Jahrbuch für Mineralogie, Abt. A., Beilage-Band* **58**, 303–348, 1928, especially pp. 338–345.

[13] *Loc. cit.*, p. 280.

# PREPARATION AND PURIFICATION OF THE TRI-IODIDES OF ANTIMONY AND ARSENIC FOR USE IN IMMERSION MEDIA OF HIGH REFRACTIVE INDEX

H. G. Fisk, *Gary, Indiana.*

In order to determine the indices of refraction of minerals, the indices of which are between 1.68 and 2.05, amorphous mixtures of piperine and the iodides of antimony and arsenic may be used (1). It is possible to use liquids only up to an index of 1.868, and those with refractive indices above 1.778 (methylene iodide saturated with sulphur) change rather rapidly by evaporation. As piperine and iodide mixtures remain constant in refractive indices a few months after they are prepared, they are especially useful.

To make these preparations, three parts by weight of antimony tri-iodide and one part of arsenic tri-iodide are mixed with the required proportion of piperine to give a mixture of the desired refractive index based upon the composition—index of refraction curve of Merwin (1). The weighed mixtures which become fluid a little above 100 degrees C. are introduced into a suitable container and heated, while being stirred, until homogeneous. After cooling, their refractive indices may be checked by means of a goniometer.

To use such mixtures as imbedding media, a small fragment of the previously prepared mixture and a few fine grains of the mineral to be examined are placed on a slide which is gently heated over a low flame, or on a hot plate. As the mass melts, the grains are mixed with it and it is covered with a small cover glass. The slide is then allowed to cool, and at the same time the mixture is pressed into a thin film which, if the mineral grains were fine enough, is sufficiently transparent to permit the microscopic determination.

Immersion media thus prepared have not been found suitable, due to numerous microscopic inclusions which cause difficulty in determining the indices of refraction of the mineral fragments. By first purifying the piperine and the iodides it has been possible to prepare media, which although not entirely free from impurities, have been found quite satisfactory.

Piperine from different sources was tried and a coarsely crystalline variety of rather large fragments gave the best results. One sample obtained from a chemical company in the powdered form, was found satisfactory only after it was twice recrystallized from ethyl alcohol. As piperine is rather soluble in hot alcohol (23 grams per 100 cubic centimeters at 60 degrees C.), and much less soluble in cold alcohol, recrystallization is readily accomplished. By filtering the hot alcoholic solution before cooling, mechanical impurities are removed.

The tri-iodides of antimony and arsenic are not obtainable from all chemical houses. Therefore, it was found desirable to prepare them.

Mellor (2) states that antimony tri-iodide can be synthesized directly from metallic antimony and iodine. This was accomplished in the following manner. The correct proportions of finely powdered antimony and iodine were mixed in a mortar and introduced into a large test tube, the lower third of which, only, was filled. Combination was caused to take place by gently heating the bottom of the tube over a low flame. The reaction takes place with some vigor and vapors of iodine are liberated; the greater part of the antimony and iodine combine. The heat of reaction is sufficient to cause the melt to remain liquid for a few moments, permitting it to be mixed by shaking the tube before solidification.

Antimony tri-iodide thus prepared was found to be unsatisfactory without purification. Attempts were first made to accomplish this by distillation from a small retort. The distilled material was found unsatisfactory. Various organic solvents were tried and at the suggestion of Dr. Merwin (3) carbon disulfide was chosen. After several trials a technique was developed whereby a pure recrystallized product was obtained. Antimony tri-iodide is only slightly soluble in carbon disulfide at room temperatures, but at 45 degrees C., just below the boiling point of the latter, it dissolves fairly readily. The crushed iodide was introduced into a 500 cubic centimeter Erlenmeyer flask with about 300 cubic centimeters of carbon disulfide. A cork stopper was inserted loosely in the mouth of the flask and it was placed in a constant temperature oven maintained at 45 degrees C. The flask was shaken from time to time until no further solution appeared to take place. Excess of uncombined antimony readily settled to the bottom of the flask and free iodine dissolved in the liquid causing a dark color. The iodine in solution reacts with metallic antimony in a short time to form more iodide. If metallic antimony was not present, a small amount (finely powdered) was added. When the dark color of the solution due to iodine was completely discharged, all solid material was allowed to settle while the flask containing the solution was kept at a temperature of 45 degrees C. After sufficient settling (two or three hours) the clear supernatant liquor was rapidly poured into a clean dry Erlenmeyer flask which was covered with a dark cloth to exclude light. This precaution was found necessary to prevent formation of light colored, fine grained decomposition products. The decanted solution was allowed to cool to room temperature and finally cooled in ice water. This temperature change caused crystallization over the bottom and sides of the flask. The cooled mother liquor was then poured back into the first flask and allowed again to act on undissolved iodide. The dissolving and decanting operations were repeated as often as necessary to produce the desired amount of pure material. Crude pulverized iodide was introduced as required. Crystals thus obtained were again purified by a second recrystallization.

According to Mellor (4) arsenic tri-iodide also can be prepared by direct union of the elements. This was found to be the case and crude arsenic tri-iodide was formed by the same method described for antimony tri-iodide. In the case of arsenic tri-iodide, the reaction of combination was not as vigorous as that taking place when antimony and iodine unite. Arsenic tri-iodide was found to be sufficiently soluble in carbon disulfide at 45 degrees C. to enable a good yield of the crystalline compound to be obtained by allowing the saturated solution, after decantation, to cool and evaporate slowly. As in the case of solution of the iodide of antimony, uncombined iodine reacts with metallic arsenic in the presence of carbon disulfide to form iodide. It was again found necessary in order to obtain a pure product, to exclude light while crystallization was taking place. With arsenic tri-iodide the last few cubic centimeters of mother liquor in contact with crystals were rejected and the crystals were rinsed rapidly with a small amount of fresh carbon disulfide.

In preparing melts of the iodides and piperine, it was found absolutely essential to avoid heating the mixtures above 135 degrees C. to prevent decomposition by excessive temperatures as pointed out by Merwin (1) and Larsen (5). The melts were best prepared in a short test tube immersed in a "Nujol" oil bath with a thermometer, the bath being heated by an electric hot plate.

For approximate determinations and comparison of refractive indices of piperine-iodide melts, the indices of which are within the range $n=1.85$ to $n=2.05$, a number of minerals have been found useful. In employing these minerals it should be recognized that the optical constants of most of them may vary from published values, due to possible changes in composition as a result of solid solution. Minerals used for this purpose include,—fayalite (pure–$2FeO \cdot SiO_2$), monazite, siderite (pure–$FeO \cdot CO_2$), zircon, synthetic $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ (6), cerargyrite and cassiterite. The writer is indebted to Dr. Wm. J. McCaughey for samples of the minerals named.

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[1] Merwin, H. E., Media of high refraction for refractive index determinations with the microscope: *Jour. Wash. Acad. Sc.*, volume **3**, pp. 35–40, 1913.

[2] Mellor, J. W., A comprehensive treatise on inorganic and theoretical chemistry, volume **9**, p. 498.

[3] Oral communication.

[4] Mellor, J. W., *loc. cit.*, p. 250.

[5] Larsen, Esper S., The microscopic determination of the nonopaque minerals: *U. S. Geological Survey Bulletin*, **679**, p. 17.

[6] W. C. Hansen, L. T. Brownmiller, and R. H. Bogue, *Jour. Am. Chem. Soc.*, 399, February, 1928.

# NOTES AND NEWS

## FELDSPARS IN THE ADIRONDACK ANORTHOSITE

Harold L. Alling, *University of Rochester.*

Barth's[1] article in the April number of the *American Mineralogist* on the composition of the feldspars of the Adirondack anorthosite, represents a beautiful piece of laboratory work. I am confident that his data will be a welcomed contribution. But as I find difficulty in accepting his conclusion that the labradorite and andesine grains are potash free, I feel called upon to review it and enlarge upon the problems there present. In the first place I feel that if we accept Barth's optical results as accurate, and interpret them on the basis of our present knowledge of the feldspars, I reach the conclusion the opposite to that stated by Barth. In other words, he, I think, failed to prove his point.

In the second place, Barth seems to have ignored the opinions of the Adirondack geologists who have faced this very problem for many years. Allow me briefly to review the literature.

Hawes[2] noted in thin sections of Adirondack anorthosites that a few feldspar grains failed to afford the twinned striations, which he, however, suspected of being plagioclase. Chemical tests demonstrate that they were dominantly soda-lime feldspars.

Cushing[3] says "The potash is in the labradorite (or other plagioclase), replacing a certain amount of soda" and "that analyses of this feldspar always show it."

Kemp[4] says "It [is] practically certain that the potash is in the orthoclase molecule and that this feldspar is in the rocks up to 5% or over." Kemp evidently at that time did not consider the possibility of orthoclase being in solid solution in the plagioclase.

Miller[5] says "The rather high percentage of potash in rocks of this character calls for explanation." He goes on to indicate that if potash feldspar is present as such he has been unable to demonstrate it in the thin sections which he has studied. Miller is uncertain whether this potash exists as a separate group of grains or forms part of the labradorite proper.

Kemp[6] took three analyses, two furnished by Leeds, and one by Joüet, and in recasting them it was necessary to employ orthoclase from 5 to 7%.

Kemp and Alling[7] show that an analysis of the Whiteface type made by Steiger on recasting produced a norm showing 66.12% of $Or_5$, $Ab_{40}$, and $An_{55}$, while an analysis of Leeds of the Mt. Marcy anorthosite gave 89.20% of $Or_5$, $Ab_{25}$, and $An_{70}$

Mawdsley[8] has studied forty thin sections of the anorthosite from the St.

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[1] Barth, Tom. F. W., Mineralogy of the Adirondack Feldspars: *Am. Mineral.*, April **1930**, pp. 129–143.

[2] Hawes, G. W., *U. S. Nat. Mus. Proc.*, **1882**, Vol. 4, pp. 134–136.

[3] Cushing, H. P., *N. Y. State Mus. Bull.* 95, **1905**, p. 335.

[4] Kemp, J. F., *N. Y. State Mus. Bull.* 138, **1910**, p. 30.

[5] Miller, W. J., *Bull. Geol. Soc. Am.*, **1918**, Vol. 29, p. 406.

[6] Kemp, J. F., *N. Y. State Mus. Bull.* 229–230, **1920**, pp. 31–32.

[7] Kemp, J. F., and Alling, H. L., *N. Y. State Mus. Bull.* 261, **1925**, pp. 37–38.

[8] Mawdsley, J. B., St. Urbain Area, Charlesvoix District, Quebec: *Canada Geol. Surv. Mem.*, **152,** 1927, pp. 18–28.

Urbain Area in Quebec, and four complete chemical analyses made by Professor Phillips of Princeton University, where the alkalies were determined in duplicate. The composition of the feldspars as determined by chemical analyses is given below.

DETERMINED BY CHEMICAL ANALYSES

| Or | Ab | An |
|---|---|---|
| 4.7 | 57.7 | 37.6 |
| 1.3 | 58.9 | 39.8 |
| 2.0 | 41.5 | 56.5 |
| 1.9 | 37.4 | 60.7 |

Mawdsley[9] states "The low content of the orthoclase molecule as found by chemical analyses, considered in conjunction with the results obtained from optical analyses of the same materials, indicates the absence or virtual absence of orthoclase in solid solution in the plagioclase of three of the samples analyzed." The evidence of this conclusion appears to be that "the quantity of the orthoclase molecule indicated by chemical analysis to be present is far less than is required for the formation of the observed perthitic rods and interstitial grains of what *appears* as orthoclase." (My italics.)

The point seems to be what is the actual nature of these interstitial grains, as well as the actual thickness and size of the blebs. Mawdsley suggests anorthoclase, which if I take the usual meaning of the word to apply here, is a soda-rich potash feldspar something of the order of K-feld. 45, Na-feld. 53, Ca-feld. 2. Whatever may be the exact composition of these interstitial grains, anorthoclase or untwinned plagioclase, it is pretty certain that it is not pure orthoclase. Furthermore, my studies of antiperthitic labradorites show that the blebs are relatively thin, thinner than many thin sections, and hence, any graphic quantitative analysis would exaggerate their bulk. I question Mawdsley's statement "The only possible explanation is that the plagioclase present has practically no orthoclase in solid solution" . . . . "the plagioclase feldspars of the St. Urban anorthosites in some, perhaps in most cases, contain practically none of the orthoclase molecule in solid solution."

Mawdsley suggests that it is "probable that the process of exsolution was so facilitated (perhaps by the plagioclase crystals being kept for a long time at a temperature close to the inversion point[10] of the solid orthoclase from the solid plagioclase),[11] that almost complete exsolution of the orthoclase from the plagioclase in the anorthosite rocks took place."

Bowen[12] notes these antiperthitic grains in the Adirondacks and suggests that either the potash feldspar blebs were "originally in solid solution in the plagioclase and that on separating from solid solution it left the plagioclase poorer in potash feldspar and therefore of higher refraction" . . . . or "that the potash feldspar

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[9] *Ibid.*, p. 6.

[10] I question whether the word "inversion" is correctly used here. I believe that the word "boundary-curve" between two solid phases would be more accurate. See Fenner, C. N., *Jour. Geol.*, Vol. 33, **1930,** pp. 159–165.

[11] Mawdsley, J. B., St. Urbain Area, Charlesvoix District, Quebec: *Canada Geol. Surv. Mem.*, 152, **1927,** p. 27.

[12] Bowen, N. L., *Jour. Geol.*, Vol. 25, **1917,** p. 221.

[blebs] . . . . formed from the portion which remained liquid last and was introduced into the plagioclase by a sort of replacement."[13]

Such suggestions are quite in conformity with the views I have expressed,[14] but none of the thermal diagrams that have been proposed show a complete separation of potash feldspars from plagioclase. That is, all of them show that plagioclase must be represented by an area and not a line. Plagioclase is in truth a ternary and not a binary system. If these blebs of the antiperthite have been introduced, the problem is complicated thereby; I am not sure if this changes my opinion of the composition of the plagioclase, however.

Barth[15] says "facts will be presented that prove the non-existence of an admixture in solid solution of potash feldspar (as well as of carnegieite.)" He suggests that chemical studies of this feldspar are difficult because of the presence of the perthites and other intergrowths which make it impossible to get pure material for the analyses. This is perfectly obvious to anyone who has studied the Adirondack feldspars. Barth used the Fedorow stage and determined the axial angle and the position of the indicatrix of 15 different crystals and plotted these in Figure 2 of the above mentioned paper. He states that he has compared these results with the position of the indicatrix of "normal" plagioclase. "All of the measurements agree with the curves for the normal plagioclase within the limits of error."[16] "It is highly improbable that an appreciable amount of either the potash feldspar or carnegieite would not cause an observable alteration of the shape of the indicatrix, and throw it far out of its normal position."

It is not entirely clear to me what Barth means by "normal position" of "normal" plagioclase. In his figure he reproduces "the positions of the optical elements in the normal plagioclase series (according to Duparc and Reinhard)." If Barth has drawn his figure on the basis of Duparc and Reinhard[17] and calls the feldspar studied by these Swiss mineralogists "normal," then it is reasonable, from a study of the chemical analyses of the feldspars (given below) to definitely conclude that "normal" plagioclase contains the potash end member.[18]

However, Duparc and Reinhard's data are based upon old analyses, the accuracy of which I have recently questioned.[19]

Barth calls the interstitial feldspar comparatively pure orthoclase, and yet records the extinction angle normal to (010) from 1° to 3°. This suggests to Barth,

[13] See Colony, R. J., *Jour. Geol.*, Vol. 31, **1923**, p. 170, fig. 1.

[14] Alling, H. L., Mineralography of the Feldspars, Part 2, *Jour. Geol.*, 31, **1923**, pp. 288–290.

Mäkinen Eero, Über die Alkalifeldspäte, *Sonderabd. aus. Geol. Föreningens. Förhandle.*, XXXIX, H. 2 (February **1917**), 149.

[15] Barth, Tom. F. W., Mineralogy of the Adirondack Feldspars: *Am. Mineral.*, April **1930**, pp. 129–143.

[16] I am unable to find where the limits of error are given.

[17] Duparc and Reinhard, La Determination des plagioclases dans coupe minces: *Mem. Soc. phy. et d'hist. nat. Geneve*, Vol. **XL**, p. 134.

[18] Alling, H. L., Indices of Refraction of the Plagioclase Feldspars: *Jour. Geol.*, Vol. 37, No. 5, July–August **1929**, p. 475.

[19] Alling, H. L., *Jour. Geol.*, 37, **1929**, pp. 462–482.

TABLE I

COMPOSITION OF PLAGIOCLASES USED BY DUPARC AND REINHARD.

| NAME | LOCALITY | COMP. AS GIVEN | | DATE OF ANALYSIS | COMPOSITION AS RECAST | | | TOTAL FELDSPAR |
|---|---|---|---|---|---|---|---|---|
| | | Ab. | An. | | K-Feld. | Na-Feld. | Ca-Feld. | |
| Albite | Greenland | 99.5 | 0.5 | 1908 | 2. | 98. | N.D. | 98.78 |
| Oligoclase | Bamle, Norway | 87. | 13. | 1869 | 2. | 84. | 14. | — |
| Oligoclase | Bakersville | 80. | 20. | 1888 | 3.3 | 74.5 | 22.2 | 98.07 |
| Basic Oligoclase | Tvedestrand | 75. | 25. | 1845 | 7.45 | 69.62 | 22.93 | — |
| Andesine | Hohenstein | 65. | 35. | — | 2* | 61. | 37. | 98.92 |
| Bytownite | Narodal | 27. | 73. | 1869 | 2* | 24. | 74. | — |

* $K_2O$ not determined. Assumed 2% K-Feld., and subtracted it from Na-Feld.

as it does to me,[20] anorthoclase. But Barth is uncertain "whether the potash feldspar is pure or whether it is an anorthoclase." How can it be a pure[21] monoclinic feldspar with an extinction angle 1° to 3°? He says some grains show an extinction of 4° to 5° and microcline cross-hatching. He gives me the impression that he calls this feldspar microcline, without realizing that many anorthoclases exhibit this type of twinning. Twinning alone is no safe criterion.[22]

Barth measured the indices of refraction of "crystals . . . . said to consist mainly of orthoclase." His results with sodium light are: $N_g = 1.5288$, $N_m = 1.5270$, $N_p = 1.5230$.

In applying these results to the diagrams furnished by Winchell[23] and modified by Alling,[24] difficulty is experienced in making them fit. It makes no difference what series is attempted. The $\gamma$-feldspars: sanidine-barbietite, the $\beta$-feldspars: orthoclase-albite, or the $\alpha$-feldspars: microcline-analbite. In any case, it is impossible to obtain results from Barth's determinations that in any way approach pure potash feldspar. Applying it to the orthoclase-albite system, ignoring for the moment any lime component, results crudely approximate $Or_{50}$, $Ab_{50}$, and if applied to the $\gamma$-feldspars, results are in the neighborhood of microcline 75, and analbite 25.

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[20] Alling, H. L., *Jour. Geol.*, Vol. 29, **1921**, p. 231.

[21] Meaning 100% $KAlSi_3O_8$?

[22] Alling, H. L., *Jour. Geol.*, Vol. 31, **1923**, pp. 357–358, 374.

[23] Winchell, A. N., *Jour. Geol.*, 33, **1925**, pp. 714–727.

[24] Alling, H. L., *Jour. Geol.*, 34, **1926**, p. 604.

Barth gives indices of refraction for the "microcline" which gives the extinction angle on the (001) phase, 15°, as follows: $N_g = 1.5293$, $N_m = 1.5268$, $N_p = 1.5225$. In applying these data to the microcline-analbite system it shows a very high percentage of soda.

Barth's conclusions are as follows, to which I have added my comments:

1. That there are two clearly separate stages of crystallization. To this I agree.

2. The andesine-labradorite is potash free. To this I do not agree.

3. Late stage feldspar; potash free oligoclase and comparatively *pure* (my italics) potash feldspar. This I cannot accept.

4. Pure labradorite melts at about 1300° C. This is true in *dry* melts at *normal* pressure which Barth recognizes.

5. Potash feldspar melts at about 1000° C. Morey and Bowen[25] have shown that potash feldspar has no true melting point; it melts incongruently.

## My Conclusions

1. The plagioclase of the Adirondack anorthosites consists of labradorite grading into andesine with an appreciable though small percentage of potash feldspar in solid solution.

2. Late stage interstitial feldspars are soda-rich anorthoclases and potash bearing oligoclases. The latter may be untwinned.

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[25] Morey, G. W., and Bowen, N. L., *Am. Jour. of Sci.*, (5), Vol. 4, **1922**, pp. 1–22.

# NOTES ON RICKARDITE, A NEW OCCURRENCE

Wm. P. Crawford, *Bisbee, Arizona.*

Rickardite was first discovered in the Good Hope mine, Vulcan, Colorado, by Dr. Loui Weiss in 1902. The mineral was associated with native tellurium and gold and silver tellurides. Qualitative tests made by A. B. Sanford proved it to be a telluride of copper and the mineral was analyzed and described by W. E. Ford[1] in 1903.

Rickardite has been mentioned from two other localities besides the type locality, the Good Hope mine. H. B. Patton[2] named rickardite as one of the minerals of the Empress Josephine mine, Bonanza, Colorado. Native tellurium, sylvanite, hessite, petzite, and empressite were also found in this mine. Patton gave no description of the occurrence, only listing it in the table of minerals. C. Erb Wuensch[3] noted the occasional presence of rickardite in small amounts in the San Sebastion mine, Salvador. According to Mr. Wuensch[4] the rickardite occurred very sparingly and was in small and irregular grains associated with pyrite. Calaverite occurred in minor quantities.

A number of years ago tellurium was detected in certain ores of the Calumet and Arizona Mining Company, Warren, Arizona, by W. W. Brostrom. The tellurium was present only in small amounts and the occurrence was limited and very erratic. No telluride minerals could be identified. The presence of tellurium was easily detected by the permanganate method of copper analysis which was used. Tellurium is precipitated upon the addition of sodium sulphite to the HCl acid solution and darkens the cuprous thiocyanate precipitate. A small amount of the black precipitate was obtained and this gave a confirmatory test for tellurium. The gold and silver content of the ore was low.

Practically all of the samples in which tellurium was present were of oxidized ore from the Briggs' mine. A pulp sample of sulphide ore from a stope on the 1400 ft. level of the Junction mine gave an unusually heavy, black precipitate and this sample was given to the writer by Mr. Brostrom.

The pulp was taken into solution by $HNO_3$ acid and $KClO_3$, evaporated to moistness and taken up with HCl acid. Sulphur dioxide was passed though the HCl acid solution and the resulting black precipitate was allowed to settle and filtered. Treatment with concentrated sulphuric acid gave the characteristic reddish color of tellurium sulphate.

About twenty grams of the pulp were panned, obtaining a sulphide concentrate of pyrite and chalcopyrite nearly free from limestone. On examination under a microscope (90 x) the concentrate showed a number of small fragments of a purple mineral. These were compared with rickardite from the original find in the Good Hope mine and appeared identically the same. The crushed material was purple and it gave a definite reaction for tellurium with sulphuric acid. No quantitative analysis was possible because of the scarcity of the material. The stope from which this sample came was inaccessible at the time of the examination and no other samples were obtainable. Ores containing a detectable amount of tellurium have not been found in the last two years.

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[1] Ford, W. E., Rickardite, a new mineral: *Amer. Jour. Sci., Ser. 4, vol.* **15,** pp. 69–70, 1903.

[2] Patton, H. B., Geology and ore deposits of the Bonanza district, Saguache County, Colo., *Colo. Geol. Survey Bulletin* **9,** p. 108, 1916.

[3] Wuensch, C. E., Geology of the San Sebastion mine, Salvador: *Min. and Sci. Press, vol.* **115,** No. 10, p. 348, Sept. 8, 1917.

[4] Wuensch, C. E., *personal communication.*

The qualitative tests and the physical characteristics of this mineral are the same as those of the type mineral and it is probably rickardite. This makes the fourth recorded occurrence of this mineral and the third occurrence in the United States.

I wish to acknowledge the assistance of Mr. W. W. Brostrom in testing this material and the use of his notes on the detection of tellurium in these ores and for the pulp sample containing the rickardite.

Dr. A. R. Crook, since 1907 curator of the Illinois Museum of Natural History, died May 30, at the age of 66 years. Dr. Crook graduated from Ohio Wesleyan University and in 1892 received his Ph.D. degree at the University of Munich. From 1893 to 1906 he served on the instructional staff of Northwestern University.

### CENOSITE: A CORRECTION

In behalf of Ward's Natural Science Establishment, Inc., and personally I wish to apologize for an incorrect statement in our offering of Cenosite in the June *American Mineralogist.* This was written very hurriedly owing to my hasty removal to a hospital for an operation and reference was not made to any literature except *Dana's System.* The occurrence at Nordmark was therefore overlooked.

GEORGE L. ENGLISH

## PROCEEDINGS OF SOCIETIES

### NEW YORK MINERALOGICAL CLUB

#### *Minutes of the April Meeting.*

A regular monthly meeting of the New York Mineralogical Club, with 66 members present, was held at the American Museum of Natural History on the evening of April 16, 1930, with President Herbert P. Whitlock in the chair.

Mr. Martin L. Ehrman of New York City and Mr. Miro Bianchi of Paterson, N. J., were elected to membership.

This being the annual meeting, the following officers were unanimously elected: President, Frederick I. Allen; First Vice-President, George E. Ashby; Second Vice-President, Horace R. Blank; Secretary, James F. Morton; Treasurer, Gilman S. Stanton.

The address of the evening was delivered by the retiring president, Herbert P. Whitlock, his subject being "*The Minerals in the Earth's Crust.*" The speaker discussed the general subject of the elements from the different viewpoints, and stressed the method approach by the geologist and the mineralogist.

In a series of colored diagrams, the speaker gave a vivid presentation of the eleven most common minerals in the earth's crust and their proportionate abundance, as well as of silica and the principal metallic oxides, with their respective contributions to the rock-forming minerals. By means of a table the speaker showed why these rock-forming minerals are common, on the basis of the proportions of the eleven commonest elements in the earth's crust.

In closing, the speaker discussed the formation of several types of minerals from magmas containing a maximum and a minimum proportion of silica.

A rising vote of thanks was extended to the speaker.

JAMES F. MORTON, *Secretary*

### *Minutes of the May Meeting.*

A regular monthly meeting of the New York Mineralogical Cub was held at the American Museum of Natural History on the evening of May 21, 1930, with President Frederick I. Allen in the chair. There were 36 members present.

Mr. E. B. Chapin of Tenafly, N. J., Mr. George B. Wilmott of Brooklyn, N. Y., and Mr. Wm. H. McClelland of New York, N. Y., were elected to membership. Sir William Henry Bragg was unanimously elected an honorary member of the Club. It was voted to present him with a diploma on behalf of the Club.

Professor Paul F. Kerr of Columbia University was the speaker of the evening, his subject being "*A Modern Mineralogical Study of Clay.*" He dwelt on the application of X-rays and microscopic methods to the study of clay, and illustrated the methods in a practical way by descriptions of several types of clay, emphasizing the following points:

The clay minerals have long provided one of the most difficult fields of mineralogical endeavor, due largely to the extremely finely divided nature of the material. In recent years, however, methods have been developed, which give promise of solving problems that have long existed concerning the nature of the clay minerals. The two most promising lines of study are a direct outgrowth of X-ray methods and petrographic research. These developments are now proving most valuable auxiliaries to the time-honored method of chemical analysis.

One of the most interesting results of this study is a reduction in the large number of mineral species generally attributed to the clay group.

An interesting discussion followed the address, and a rising vote of thanks expressed the appreciation of the members.

JAMES F. MORTON, *Secretary*

## NEW MINERAL NAMES

### **Arandisite**

F. C. PARTRIDGE: A new tin mineral from South-west Africa. *Trans. Geol. Soc., S. Africa*, **32**, 171–176, 1930.

NAME: From the locality, Arandis.

CHEMICAL PROPERTIES: A silicate of tin. Analysis (by H. G. Weall): Moisture 5.0, Ign. loss 3.5, $SiO_2$ 16.2, $Al_2O_3$ 2.7, $Fe_2O_3$ 1.3, Cu 0.9, $SnO_2$ 70.9; total 100.5. Decomposed by sulphuric acid. Does not reduce with zinc and HCl. B. B. infusible but turns brown or black. In closed tube yields water which is faintly alkaline to litmus. The mineral does not darken. With fluxes yields dispersed beads of tin. With cobalt nitrate gives a blue crust.

Physical and Optical Properties: Color, varies from pale green through bright green to deep grayish green, with bright apple green as the predominant shade. Luster, waxy to resinous. Streak, nearly white with tinge of yellowish green. Fracture, subconchoidal to uneven. $H=5$. Sp. Gr. 4.12. Mainly isotropic. Made up of two components, a pale green to colorless one ($n=1.706$) and green to green yellow fibers of varying size ($n=1.82$). Apparently a colloid showing incipient crystallization.

Occurrence: Found in a tin mine 23 miles north of Arandis, Southwest Africa, with cassiterite, quartz and iron and copper sulfides in limestone. (T. W. Gevers; a hydrothermal Deposit of Cassiterite near Arandis, Southwest Africa. *Trans. Geol. Soc. S. Africa*, **32**, 65–170, 1930).

W. F. Foshag

## Maufite

F. E. Keep: Notes on Nickel Occurrences in the Great Dyke of Southern Rhodesia. *Trans. Geol. Soc., S. Africa*, **32**, 103, 1930.

Name: In honor of H. B. Maufe, Director of the Southern Rhodesia Geological Survey.

Chemical Properties: A silicate of nickel, aluminum and other bases; $(Mg,Ni,Fe)O.2Al_2O_3.\ 3\ SiO_2.\ 4H_2O$. Analysis (by E. Golding): $SiO_2$ 33.26, $Al_2O_3$ 36.81, $Fe_2O_3$ 0.79, FeO 0.68 CaO tr., NiO 4.28, $H_2O+$ 13.67, $H_2O-$ 5.71. Total 99.98. No $Co_2$, $TiO_2$, $SO_3$, Cl, F, $Zr_2O_3$, $Cr_2O_3$, BaO, MnO, or CuO.

Physical and Optical Properties: Color emerald green, slightly dichroic. Made up of fibrous sheaves at acute angles with one another. Optical elongation negative. H-3. Sp. Gr. 2.27.

Occurrence: Found as a quarter-inch seam in dark red speckled serpentine rock adjacent to a small dolerite dyke, one and one half miles northeast from the Umvukwe Geodetic Station, Umvukwe Mts., Southern Rhodesia.

W. F. F.

## Zamboninite

F. Stella Starrabba: Zamboninite-una nuova specie minerale. *Boll. Soc. Geol. Ital.*, **48**, pp. 259–263, 1930.

Chemical Properties: Calcium magnesium fluoride; formula: $CaF_2.2MgF_2$. Analysis: Mg 24.26, Ca 17.94, Mn not determined, Al 0.41, Fe trace, Na 0.31, K 0.05, F 55.57, $H_2O$ 1.63; Sum 100.17. No Si, Cl, S. Easily fusible before the blowpipe with intumescence, forming finally an infusible mass. Partly soluble in conc. HCl and $HNO_3$; soluble in $H_2SO_4$, with evolution of HF.

Crystallographic Properties: Not determined, probably orthorhombic.

Physical and Optical Properties: Finely radiating fibrous structure, color white. Sp. Gr. 2.98–3.00. Birefringence weak, biaxial positive, parallel extinction. $n$ maximum$=1.411$, minimum$=1.405$.

Occurrence: Forms small masses on crevices of lava of 1669, at Monti Rossi, Etna, from fumarole deposits.

H. S. Washington

## ADDITIONAL DATA

### Kramerite

W. T. Schaller: Borate minerals from the Kramer District Mohave Desert, California. *U. S. Geol. Surv. Prof. Paper*, **158,** 139–146, 1930.

Name: From the locality: Kramer, California.

Chemical Properties: A hydrous borate of soda and lime. $Na_20 . 2CaO . 5B_2O_3 . 10H_2O$. Analysis: $Na_2O$ 8.34, CaO 15.11, $B_2O_3$ 49.30, $H_2O$ 25.40, $SiO_2$ 0.57, $Al_2O_3$ 0.42, Insol. 1.55. Sum 100.93 (average of 3 analyses). Soluble in hydrochloric acid.

Heated in closed tube, decrepitates, gives off water, turns opaque white, swells slightly and fuses imperfectly to clinkerlike masses. Before the blowpipe fuses readily to a clear bubbly glass, giving a yellow flame.

Crystallographical Properties: Monoclinic, prismatic. $a:b:c = 1.1051:1:0.5237$. $\beta = 72°16'$ $p_0' = 0.4976$, $q_0' = c = 0.5237$, $e' = 0.3197$. Forms $a(100)$, $b(010)$, $m(110)$, $e(011)$, $t(101)$, $d(101)$, $p(111)$, $o(111)$.

Physical and Optical Properties: Colorless, transparent. Cleavage $m(110)$ perfect. Luster vitreous and shining. Hd. 4½. Sp. Gr. 2.141.

Biaxial, positive. $2V = 73°$, $2E = 126°$. Dispersion $\rho > \nu$. Elongation positive. $\alpha = 1.515$, $\beta = 1.525$, $\gamma = 1.544$. Plane of the optic axes is parallel to $b(010)$. $Y = b$, $Z \wedge c = 12°$.

Occurrence: Found as radiating prismatic needles in clay, massive borax or kernite at the Kramer District, Kern Co., Calif.

Discussion: [This mineral has been described under the name probertite by A. S. Eakle, *Am. Mineralogist,* **14,** 427, 1929. The analysis given there differs greatly from those given by Schaller. W. F. F.]

W. F. F.

### Kernite

Waldemar T. Schaller: Borate Minerals from the Kramer District, Mohave Desert, California. *U. S. Geol. Surv. Prof. Paper*, **158,** pp. 137–170, 1930.

Original Description: This Journal, **12,** p. 24–25, 1927.

Crystallographical Properties: Monoclinic, habit domatic. $a:b:c = 1.5230:1:1.6989$. $\beta = 71°08'$, $p_0' = 1.1788$, $q_0' = 1.6989$, $e' = 0.3417$. 32 forms of which $c$, (001), $a$, (100), $e(011)$ and $D(101)$ are the common ones. Cleavages $c$ and $a$ perfect, $D$ distinct; perhaps $e$ and $b$ also.

Optical Properties: Biaxial negative. $2V = 80°$, $2E = 142°$. Dispersion distinct $\rho > \nu$. $\alpha = 1.454$, $\beta = 1.472$, $\gamma = 1.488$. Plane of the optic axes is normal to $b(010)$; $X$ and $Y$ lying in the plane of symmetry, and $Z = b$. $X \wedge C = 70\frac{1}{2}°$.

W. F. F.